Journal of Environmental Science, Health & Sustainability, 2025, 1(2), 79–84
https://journals.enviromindsolutions.com/jeshs
eISSN: 3067-946X

Editorial

Sustainable agriculture in a changing climate: Unlocking climate-smart agriculture for securing global food systems

Md Maruf Billah[1,2,3], Ravi Naidu[1,2], Brajesh K. Singh[4] and Mohammad Mahmudur Rahman[1,2*]

[1]*Global Centre for Environmental Remediation (GCER), College of Engineering, Science and Environment, The University of Newcastle, Callaghan, New South Wales 2308, Australia*
[2]*crcCARE Pty Ltd, ATC Building, University Drive, Callaghan, NSW 2308, Australia*
[3]*Agrotechnology Discipline, Khulna University, Khulna 9208, Bangladesh*
[4]*Hawkesbury Institute for the Environment, Western Sydney University, Penrith South, NSW, Australia*

How to cite

Billah, M.M., Naidu, R., Singh, B.K., Rahman, M.M., 2025. Sustainable agriculture in a changing climate: Unlocking climate-smart agriculture for securing global food systems. Journal of Environmental Science, Health & Sustainability, 1(2), 79–84.
https://doi.org/10.63697/jeshs.2025.10044

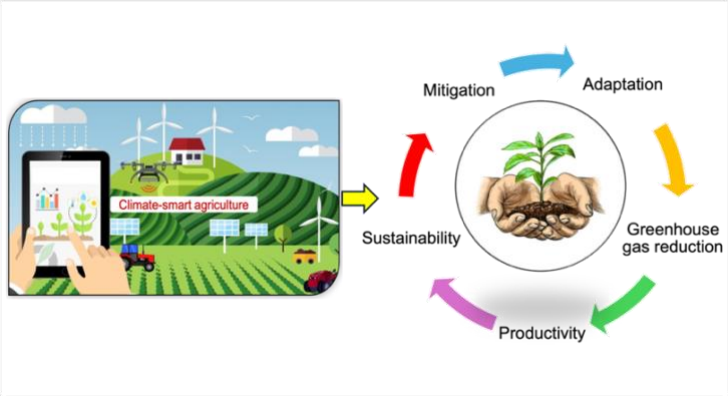
Article info

Received: 2 August 2025
Revised: 20 August 2025
Accepted: 22 August 2025
Published: 30 August 2025

Keywords

Sustainable agriculture
Climate change
Adaptation
Smart farming system
Food security

Graphical abstract



Highlights

- *Agriculture is the mainstay of the world's economy and support global food security.*
- *Climate change and variabilities are the key concern to farm sustainability.*
- *Climate-smart agriculture is integral to sustainable agricultural development.*
- *Farmers' training, incentives, improved agricultural services are highly recommended.*

Abstract

Agriculture is the foundation of human civilization and the main source of livelihoods for millions. However, as global food demand rises to sustain the growing population, agricultural land is shrinking due to degradation and contamination. Additionally, farming practices are increasingly affected by natural and human-made factors, with climate change becoming a major threat to agricultural sustainability. To meet the food needs of a growing population and adapt to climate change, adopting climate-smart farming systems and empowering farmers to manage resources more effectively is crucial. Climate-Smart Agriculture (CSA) offers a promising way to tackle the urgent challenges of sustainable farming by improving resilience, lowering emissions, and boosting productivity. Although many farming communities have started adopting CSA innovations at the farm level, they still face various challenges, such as limited training resources, inadequate information, and poor extension services. To promote wider adoption and successful implementation of these practices, policymakers and relevant organizations must focus on enabling strategies like providing incentives for innovation, farmer training programs, and better access to agricultural services.

**Corresponding author: mahmud.rahman@newcastle.edu.au (MMR)*
© 2025 The Authors. Published by Enviro Mind Solutions.
Handling Editor: Dr. Bibhash Nath with assistance from Dr. Laurent Charlet.

1 Introduction

Agriculture is the mainstay of the global economy, covering around 37% of the earth's land surface, consuming nearly 70% of global freshwater resources and contributing up to one third of anthropogenic greenhouse gas (GHG) emissions to the atmosphere (Crippa et al., 2021; IPCC, 2021). There exists a mutual relationship among agriculture, climate change, farm sustainability and food security (Bank, 2013). Agricultural productivity is mainly affected by local climatic conditions, including temperature, precipitation, and humidity (Bruinsma, 2017). On the contrary, intensive and unsustainable farming practices are major contributors to climate change, primarily through the emission of potent GHGs, particularly methane and nitrous oxide (MacDicken, 2015).

Farming practices are challenged by numerous factors, with climate change recognized as one of the main drivers (IPCC, 2013). Besides, the global population is rising rapidly, increasing the demand for food and other basic needs, whereas cultivable agricultural land continues to decline (Billah et al., 2025). It is anticipated that by the 2080s, the world's population will be around 9.7 billion, necessitating a 70% increase in agriculture production to meet global food demand, which is a matter of concern (FAO, 2016). At the same time, there is a growing need to ensure that food production remains sustainable in the face of environmental change. In this situation, adopting climate-smart farming practices and enabling farmers to manage their resources more precisely are essential for producing food sustainably and feeding the expanding global population (Lipper et al., 2010).

Climate-Smart Agriculture (CSA) is a set of agricultural practices or interventions that pursue to satisfy three basic determinations such as sustainably increase agricultural production to boost income and food security; adapt and build resilience to climate extremes; and create opportunities to reduce or remove GHGs emission, wherever plausible (Mann et al., 2009; Lipper et al., 2014). Globally, CSA is considered the powerhouse of sustainable agricultural development (Berhanu et al., 2024; Zheng et al., 2024). Moreover, CSA can consolidate farmer's livelihoods and improve carbon sequestration by creating carbon sinks and reducing GHGs emissions from the farming sectors (Raj et al., 2018; Paul et al., 2023).

Therefore, to mitigate the adverse impacts of climate change on farming practices and promote sustainable agricultural development, it is essential to strengthen farmers' adaptive and resilience capacity. Strategic adaptation and effective implementation of CSA interventions offers a viable pathway towards achieving the United Nation's Sustainable Development Goals (SDGs) effectively.

2 Adaptation to climate-smart agriculture

Addressing the multifaceted challenges posed by climate change requires strengthening the adaptive and resilient capacity of agriculture stakeholders, which is critical for ensuring farm sustainability (Palombi and Sessa, 2013). Adoption of CSA interventions as a viable strategy is highly recommended for sustainable agriculture development by the FAO (2016). The effectiveness of CSA interventions has been explored in reducing vulnerabilities to climate extremes and improving the socio-economic well-being of farmers (Berhanu et al., 2024).

It has been noted that farmers can advance smart farming systems through improved management of crops, livestock, fisheries, soil, water, and control of insect-pest infestations and diseases (Matteoli et al., 2020; Agustini, 2021). Universally, CSA is considered the engine of farm sustainability (Berhanu et al., 2024; Zheng et al., 2024). A study highlighted that CSA technologies are effective in reducing vulnerabilities in response to extreme climate and upgrading farmers' socio-economic situations (Berhanu et al., 2024).

For widespread agricultural development, the successful dissemination and adoption of CSA innovations must be prioritized globally, particularly in developing nations like Bangladesh and India. Scholars (Raghuvanshi et al., 2018; Wekesa et al., 2018; Hussein, 2024) claimed that CSA practices offer numerous benefits, including increasing productivity and income, decreasing GHG emissions, fostering adaptation and mitigation capacities, and safeguarding food security. These benefits are supported by the three foundational pillars of CSA technologies, which collectively define its importance for agricultural sustainability (**Fig. 1**).

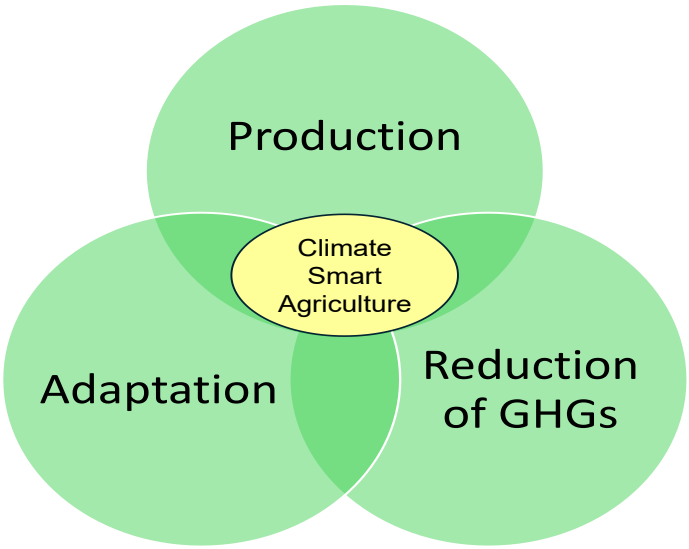


Figure 1. *Three basic pillars of CSA interventions.*

3 Agricultural sustainability in a changing climate

Agriculture remains at the heart of global economic systems, serving as a primary source of food, raw materials, and employment opportunities for the growing population. Despite its central role, the agricultural sector faces a multitude of threats (Bryan et al., 2009; Palombi and Sessa, 2013). It continues to be a vital livelihood source for millions, yet sustainable agricultural development is increasingly challenged by multiple issues such as land degradation and soil erosion, water scarcity and pollution, overuse of pesticides and antibiotics, biodiversity loss, and, most critically, climate change (Masson-Delmotte et al., 2022; Billah et al., 2023).

Climate change characterizes the most acute challenge of the 21st century, significantly disturbing the world's food security and posing the foremost threat to humanity (IPCC, 2021). Its cascading impacts extend across critical sectors such as agriculture, forestry, environment, and biodiversity (FAO, 2016). It has been stated that due to the severity of climate variabilities, substantial crop yield losses have been projected: up to 35% of rice, 20% of wheat, 60% of maize, 13% of barley, and 50% of sorghum, varying by the nature and extent of impacts, location, and time (Porter et al., 2014).

It has been predicted that freshwater scarcity is a severe challenge for farm sustainability, as present agriculture favors high water consumption crops or export products. Thus, low-water-consuming crops, such as millet, should be reintroduced for agricultural sustainability (Helena, 2025). Farm sustainability and feeding the world's growing population now and in the future constitute a challenging issue (Nelson et al., 2009; McGuire, 2015). In this situation, farming practices all over the world must be fundamentally transformed to address the increasing and linked challenges of climate change and the rising scarcity of food and water resources (Bruinsma, 2017).

4 Key challenges to successful diffusion and implementation of CSA interventions

The potential diffusion and adoption of CSA interventions are of great significance for sustainable agricultural development. Several studies (Mathews et al., 2018; Matteoli et al., 2020) highlighted that adopting smart farming practices is essential to mitigate the adverse effects of climate variability and enhance farm productivity. However, CSA remains an innovation, and agriculture stakeholders often face multiple barriers to its successful adoption (Billah et al., 2025). These include inadequate awareness and knowledge, financial hardship, policy research, limited market access, and infrastructural issues, which are the major constraints to the successful diffusion of CSA innovations (Zerssa et al., 2021; Wakweya, 2023).

Moreover, factors such as farmer illiteracy, inadequate training opportunities, weak extension services, gender related barriers, lack of farmers' organizations, limited access to credit and input facilities, inadequate information and communication services further hinder the widespread adaptation to CSA practices (McCarthy et al., 2011; Mutoko et al., 2015; Bhattacharyya et al., 2020; Billah et al., 2024). The major perceived challenges of the successful adoption and diffusion of CSA interventions are shown in **Figure 2**.

5 Interventions and implementation of smart agricultural practices

Farming communities, especially in developing nations of Asia and Africa, are increasingly adopting numerous CSA interventions to promote and upscale smart farming systems. A case study from Bangladesh reported that adoption of CSA practices at the farm level is decidedly effective and significantly contributes to sustainable crop production (Billah and Hossain, 2017). Among the widely adopted CSA practices, stress-tolerant crop varieties, alternative irrigation regimes, integrated pest management, conservative agriculture, and access to climate information services have shown considerable promise (Bhattacharyya et al., 2020; Hussein, 2024).

Additionally, Paul et al. (2023) found that integrated pest management, stress-tolerant varieties, homestead gardening, conservation agriculture, and use of high-yielding crops are commonly adopted CSA interventions. A study from Ethiopia emphasized water management, crop management, soil fertility, agroforestry, and livestock management as potential CSA interventions (Hussein, 2024). The following pathways are highly recommended for farm-level adaptation to CSA interventions (**Fig. 3**).

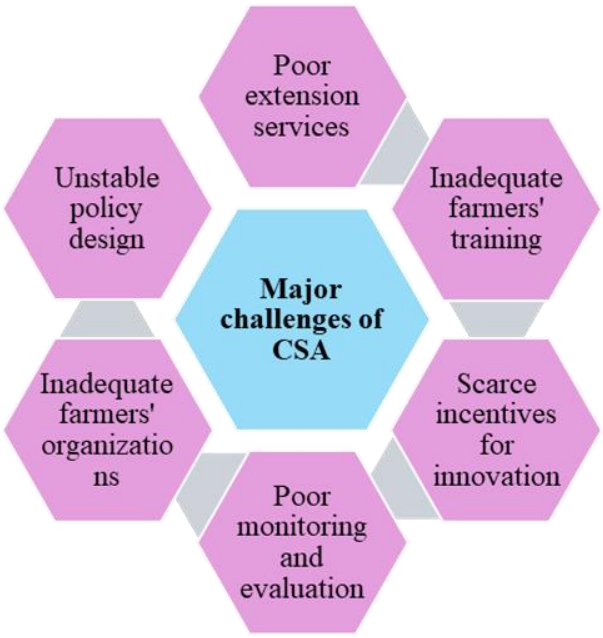


Figure 2. *Key challenges to effective implementation of CSA interventions.*

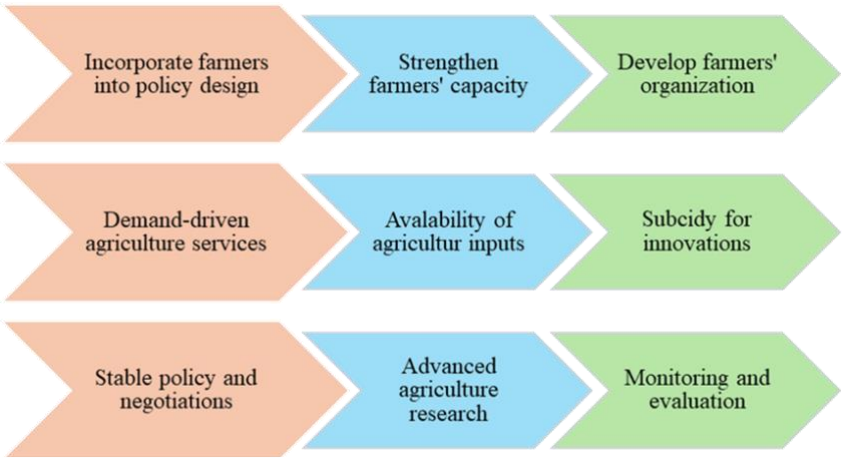


Figure 3. *Initiatives for potential adaptation to CSA interventions.*

6 Conclusion and future research directions

Farming communities are increasingly adopting various CSA initiatives; however, concerned authorities and policymakers must implement enabling strategies such as incentives for innovation, stakeholder training, technical field support, and robust monitoring, and evaluation to strengthen the smart farming system. Additionally, interdisciplinary research that includes diverse stakeholder perspectives and utilizes advanced analytical tools is urgently needed to identify the specific challenges and opportunities related to the adaptation and implementation of CSA technologies. Enhancing CSA not only promotes agricultural sustainability but also plays a vital role in achieving the United Nations SDGs.

7 Acknowledgement

Science and Technology Fellowship Trust, Bangladesh is widely acknowledged for supporting the Doctor of Philosophy study for the first author. We also acknowledge the University of Newcastle, Australia, for providing Research Training Program fund to support this study.

8 Data availability statement

The data that supports this research will be shared upon reasonable request to the corresponding authors.

9 Author contributions

MMB: conceptualization, data curation, and writing – original draft. RN: supervision, and writing – review & editing. BKS: writing – review & editing. MMR: methodology, resources, supervision, validation, and writing – review & editing. All authors approved the final version of the manuscript.

10 Conflict of interest

The authors declare that they have no known competing financial Interests or personal relationships that could have appeared to influence the work reported in this paper.

11 Ethical statements

Not applicable.

12 Copyright statement

This is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY NC ND) license (https://creativecommons.org/licenses/by-nc-nd/4.0/). © 2025 by the authors. Licensee Enviro Mind Solutions, Connecticut, USA.

References

Agustini, D.T., 2021. Adaptation strategies of smallholder farmers using climate-smart agriculture: The case of Rejosari Village, Indonesia. University of Twente Inc., pp. 1–64.

Bank, W., 2013. Policy brief: Opportunities and challenges for climate-smart agriculture in Africa. Washington DC: World Bank Inc., pp. 1–8. http://documents.worldbank.org/curated/en/111461468202139478

Berhanu, A.A., Ayele, Z.B., Dagnew, D.C., 2024. Impact of climate-smart agricultural practices on smallholder farmers' resilience in Ethiopia. Journal of Agriculture and Food Research, 16, 101147. https://doi.org/https://doi.org/10.1016/j.jafr.2024.101147

Bhattacharyya, P., Pathak, H., Pal, S., 2020. Climate smart agriculture: Concepts, challenges, and opportunities. Springer: Singapore, 1–193. https://doi.org/10.1007/978-981-15-9132-7

Billah, M., Rahman, M.M., Mahimairaja, S., Lal, A., Srinivasulu, A., Naidu, R., 2025. Constraints and prospects of adoption of climate smart agriculture interventions: Implication for farm sustainability. Climate Smart Agriculture, 2, 100066. https://doi.org/https://doi.org/10.1016/j.csag.2025.100066

Billah, M.M., Hossain, M.A., 2017. Role of climate smart agriculture technologies in sustainable crop production by the coastal farmers of Bangladesh. Imperial Journal of Interdisciplinary Research, 3, 398–403.

Billah, M.M., Rahman, M., Naidu, R., 2023. Effect of excessive use of agrochemicals on farming practices: Bangladesh perspectives. International Journal of Agricultural Extension, 11, 79–90. https://doi.org/https://doi.org/10.33687/ijae.011.001.4526

Billah, M.M., Rahman, M.M., Mahimairaja, S., Lal, A., Naidu, R., 2024. Farmers' exposure to communication media in receiving agriculture extension and rural advisory services for farm sustainability. Journal of Sustainable Agriculture and Environment, 3, e70000. https://doi.org/https://doi.org/10.1002/sae2.70000

Bruinsma, J., 2017. World agriculture: towards 2015/2030: An FAO study. 1st edition, Routledge: London, 444. https://doi.org/10.4324/9781315083858

Bryan, E., Deressa, T.T., Gbetibouo, G.A., Ringler, C., 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environmental Science & Policy, 12, 413–426. https://doi.org/https://doi.org/10.1016/j.envsci.2008.11.002

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N., Leip, A., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2, 198–209. https://doi.org/https://doi.org/10.1038/s43016-021-00225-9

FAO, 2016. The State of Food and Agriculture: climate change, agriculture and food security. In: FAO Rome, Italy, pp. 1–220.

Helena, H., 2025. How can England possibly be running out of water? The Guardian, https://www.theguardian.com/news/ng-interactive/2025/aug/17/how-can-england-possibly-be-running-out-of-water?CMP=share_btn_url

Hussein, A., 2024. Climate smart agriculture strategies for enhanced agricultural resilience and food security under a changing climate in Ethiopia. Sustainable Environment, 10, 2345433. https://doi.org/https://doi.org/10.1080/27658511.2024.2345433

IPCC, 2013. Managing the risks of extreme events and disasters to advance climate change adaptation. Economics of Energy & Environmental Policy, 2, 101–113.

IPCC, 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://dx.doi.org/10.1017/9781009157896

Lipper, L., Mann, W., Meybeck, A., Sessa, R., 2010. Climate smart agriculture: policies, practices and financing for food security, adaptation and mitigation. In: FAO, Rome, Italy, pp. 1–41.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., 2014. Climate-smart agriculture for food security. Nature Climate Change, 4, 1068–1072. https://doi.org/https://doi.org/10.1038/nclimate2437

MacDicken, K.G., 2015. Global forest resources assessment 2015: What, why and how? Forest Ecology and Management, 352, 3–8. https://doi.org/https://doi.org/10.1016/j.foreco.2015.02.006

Mann, W., Lipper, L., Tennigkeit, T., McCarthy, N., Branca, G., Paustian, K., 2009. Food security and agricultural mitigation in developing countries: Options for capturing synergies. Rome, Italy: FAO Inc., pp. 1–77.

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., 2022. Global Warming of 1.5 C: IPCC special report on impacts of global warming of 1.5 C above pre-industrial levels in context of strengthening response to climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press. https://doi.org/10.1017/9781009157940

Mathews, J.A., Wentink, G. J., Kruger, L., 2018. Climate-smart agriculture for sustainable agricultural sectors: The case of Mooifontein. Jàmbá: Journal of Disaster Risk Studies, 10, 1–10. https://doi.org/https://hdl.handle.net/10520/EJC-e35d25df5

Matteoli, F., Schnetzer, J., Jacobs, H., 2020. Climate-smart agriculture (CSA): An integrated approach for climate change management in the agriculture sector. In: Leal Filho, W., Luetz, J., Ayal, D. (eds) Handbook of Climate Change Management. Springer, Cham., pp. 1–29. https://doi.org/10.1007/978-3-030-22759-3_148-1

McCarthy, N., Lipper, L., Branca, G., 2011. Climate-Smart Agriculture: Smallholder Adoption and Implications for Climate Change Adaption and Mitigation. FAO Rome.

McGuire, S., 2015. FAO, IFAD, and WFP. The state of food insecurity in the world 2015: Meeting the 2015 international hunger targets: Taking stock of uneven progress. Advances in Nutrition, 6, 623–624. https://doi.org/https://doi.org/10.3945/an.115.009936

Mutoko, M.C., Rioux, J., Kirui, J., 2015. Barriers, incentives and benefits in the adoption of climate-smart agriculture: Lessons from the MICCA pilot project in Kenya. Food and Agriculture Organization of the

United Nations FAO: Nairobi, Kenya, pp. 1–76. https://openknowledge.fao.org/handle/20.500.14283/i4396e

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., Lee, D., 2009. Climate change: Impact on agriculture and costs of adaptation. International Food Policy Research Institute, Washington, D.C.

Palombi, L., Sessa, R., 2013. Climate-smart agriculture: Sourcebook. FAO: Rome, Italy, xi+557. http://www.fao.org/3/a-i3325e.pdf

Paul, M., Aihounton, G.B.D., Lokossou, J.C., 2023. Climate-smart agriculture and food security: Cross-country evidence from West Africa. Global Environmental Change, 81, 102697. https://doi.org/10.1016/j.gloenvcha.2023.102697

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., Travasso, M.I., 2014. Food security and food production systems. Cambridge University Press, pp. 485–533.

Raghuvanshi, R., Raj, S., Bhattacharjee, S., 2018. Climate smart agriculture and advisory services: Approaches and implications for future. MANAGE Discussion Paper 1, MANAGE Centre for Agricultural Extension Innovations, Reforms and Agripreneurship (CAEIRA), National Institute of Agricultural Extension Management, Hyderabad, India, pp. 1–42.

Raj, A., Jhariya, M., Bargali, S., 2018. Climate smart agriculture and carbon sequestration. New India Publishing Agency (NIPA): New Delhi, 1–19.

Wakweya, R.B., 2023. Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security. Journal of Agriculture and Food Research, 14, 100698. https://doi.org/https://doi.org/10.1016/j.jafr.2023.100698

Wekesa, B.M., Ayuya, O.I., Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: Micro-level evidence from Kenya. Agriculture and Food Security, 7, 1–14. https://doi.org/https://doi.org/10.1186/s40066-018-0230-0

Zerssa, G., Feyssa, D., Kim, D.-G., Eichler-Löbermann, B., 2021. Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. Agriculture, 11, 1–25. https://doi.org/https://doi.org/10.3390/agriculture11030192

Zheng, H., Ma, W., He, Q., 2024. Climate-smart agricultural practices for enhanced farm productivity, income, resilience, and greenhouse gas mitigation: A comprehensive review. Mitigation and Adaptation for Strategic Global Change, 29, 1–38. https://doi.org/https://doi.org/10.1007/s11027-024-10124-6

Publisher's note

The author(s) are solely responsible for the opinions and data presented in this article, and publisher or the editor(s) disclaim responsibility for any injury to people or property caused by any ideas mentioned in this article.